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SAFETY GUIDELINES FOR THE OPERATION OF THE DREO 10M EMP SIMULATOR DREMPS (U)

by

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DEFENCE RESEARCH ESTABLISHMENT OTTAWA
TECHNICAL NOTE 93-5

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Radiation Effects Section
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ABSTRACT

This technical memorandum outlines the inherent hazards associated with the operation of the DREO 10 meter Electromagnetic Pulse Simulator (DREMPS) and defines the procedures that need to be followed during operation and maintenance of the system. It is intended that this technical note be provided to and read by all personnel who will be participating in EMP measurements using DREMPS.

RÉSUMÉ

Ce mémorandum technique décrit les dangers inhérents associés à l'opération du simulateur d'impulsion électro-magnétiques (IEM) de 10 m (DREMPS) du CRDO et les démarches à suivre pendant l'opération et l'entretien du simulateur. Ce mémorandum doit être distribué et lu par tout le personnel participant aux mesures IEM utilisant le simulateur.

Executive Summary

DREO has recently completed building a large facility to simulate the electromagnetic pulse (EMP) that would be produced by the explosion of a nuclear weapon outside the atmosphere. This EMP represents a threat to military electronic systems.

To generate this EMP, a high voltage (600kV) pulse generator is used. As with all high voltage equipment, the EMP simulator contains inherent hazards. Operators of the facility must follow strict safety precautions in its operation and maintenance.

This technical note outlines in some detail the hazards that exist as well as procedures that must be followed to ensure safe operation and maintenance of the facility. It is intended to be provided to and read by all personnel who will be working in the facility.

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1.0 INTRODUCTION

In 1992, the construction of a 10m electromagnetic pulse (EMP) simulator was completed by the Electronics Division of DREO. This simulator is intended to generate very short pulses (1 μs) of intense electromagnetic fields in order to examine the interaction of these fields with electronic systems. To generate these fields, a 600 kV pulse generator, designed by Maxwell Laboratories, is used.

A system such as the 600 kV Maxwell generator used in the DREO 10m EMP Simulator, is hazardous if improperly used. The pulser system can be used safely and effectively however, provided that close attention is paid to the principles of safety, good operating procedures and proper maintenance. It is essential that all personnel associated with the pulser be competent in working with various types of high voltage equipment. Safe and formal operating procedures must be established. In addition, procedures must be established for dealing with emergencies which might arise.

A high voltage pulser presents a number of hazards that are potentially lethal. These range all the way from the obvious danger of direct personnel contact with the high voltage electrical connections of the pulser system to other more subtle hazards. For example, the failure of an insulator can without warning present high voltage where it is not expected. Such hazards are not always obvious. A lethal electric shock can be received from a capacitive high voltage system, even after the power supply has been turned off and disconnected, even after it has been shorted to ground, and even after many days have elapsed since it was last used. Always be especially cautious if the system is acting in an unusual or improper fashion.

In this document the procedures are given for safe operation of the DREO 10m EMP Simulator. The document starts with the definitions of the specific terms, used in the procedures. In Section 3, the inherent hazards of high voltage pulsers with their general safety precautions are briefly discussed. In Section 4, the specific precautions for the Maxwell 600 kV pulser are given. The general rules for safe operation of the EMP-Simulator are addressed in Section 5.

The procedures for operating the pulser are subdivided into daily start-up, normal shot cycle and system shutdown, each with its own checklist. Section 6 discusses switching from high to low voltage range and visa versa. Finally Section 7 reviews the safety precautions for maintenance and troubleshooting as detailed in the pulser manual [8.1]

2.0 DEFINITIONS

EMP

ElectroMagnetic Pulse. The electromagnetic wave that is produced by the EMP Facility. It is similar to the intense radio wave that would be generated by a nuclear detonation.

Site

The area inside the chain link fence around the EMP Facility.

Site Crew

Everyone on the site. This includes visitors.

Site Safety Officer

The person on site who is responsible for site safety. He is also responsible for the operation of the pulse generator.

Generator Building

The building at the beginning of the transmission line. It has two rooms - one contains a shielded room and the other contains the high voltage Marx generator that launches the EMP down the transmission line.

Test Volume

The space between the top plate of the transmission line and the test pad. This is the area where equipment is normally placed for testing its response to the EMP.

Terminator Building

The building at the end of the transmission line. It houses a network of resistors (the termination) for absorbing the EMP when it reaches the end of the transmission line.

Measurement Building

The building at the side of the test pad. The signals from sensors in the test volume are measured here.

Control Room

The shielded room in the generator building. It houses the controls for the high voltage pulse generator in the adjacent room. The pulser operator and one other crew member are usually in the control room.

Measurement Room

The shielded room in the measurement building. It houses the equipment used for measuring, recording and analysing signals from sensors in the test volume. The crew chief and other crew members responsible for making the measurements are in this room during the firing sequence.

Shorting Bar

A grounded metal rod with a long insulating handle. It is touched to various components of the generator to remove residual charge.

Lightning Cables

These are two cables that form a low resistance connection from the top to the bottom plate of the transmission. They are clamped to the transmission line where it passes through the main window of the generator room. They protect the generator from lightning strokes to the transmission line and are removed during normal operation.

3.0 SAFETY PRECAUTIONS

WARNING

Read this section in its entirety before operating or servicing the components of this system. As with all industrial equipment, the DREO EMP simulator contains inherent hazards requiring strict safety precautions in its operation and maintenance.

Although the design of the DREO Bounded Wave EMP Simulator Pulse generator includes devices for the protection both operator and machine, safe use of the system depends upon the operator. This section describes the potential hazards of the system and recommends precautions appropriate for each.

Safe and reliable operation can be expected if the machine is operated by personnel acquainted with its function and who follow the procedures outlined in this manual. Anyone not familiar with this system should study this entire manual thoroughly before attempting to operate or service the system or components. Only qualified personnel should attempt to operate this system.

One of the biggest contributors to a safe operating site, is good housekeeping coupled with orderly procedures and a prescribed routine. Site operation should always be under the direction of a single individual who is responsible for safety on the site. This individual should have authority to interrupt operations if an unsafe condition is seen to exist by anyone.

An operating routine as well as special maintenance procedures should be established to insure that the pulser is kept in good operating condition.

3.1 Safety Hazards

As with all high voltage equipment, the EMP simulator contains inherent hazards. Operators must follow strict safety precautions in its operation and maintenance.

Some of the hazards inherent to this system are:

a. Electric shock
b. Pneumatic energy
c. Fire
d. Transformer oil
e. SF_6 gas

f. Electromagnetic radiation
g. Ionizing radiation
h. Capacitor Rupture

A discussion of each of these hazards follows.

3.1.1. Electric Shock Hazard

WARNING

High voltage is used in the operation of this equipment. Death on contact may result if you fail to observe safety precautions. Learn where the areas with dangerous high voltage are in each piece of equipment. Do not touch high voltage connections when installing, operating, or maintaining this equipment. Lethal voltages may be present in the system even after firing. Before working inside the equipment, remove line power, turn off power supply, and ground points of high voltage potential with a shorting bar.

The following safety precautions are recommended:

a. Keep away from live circuits. Remove line power, turn off the high voltage power supply (HVPS), and and trigger generator. Remove all keys before working on equipment;

b. Use an insulated, hand-held shorting bar to discharge and ground all capacitors before touching high voltage circuits. High voltage may be present in capacitors even after firing;

c. Never operate, service, or adjust the equipment except in the presence of someone who can render aid in case of electrical shock;

d. Instruct all users and those involved with maintenance in modern methods of cardiopulmonary resuscitation (CPR);

e. Advise users of the fastest access to medical help in case of electrical shock. Post signs with this information; and

f. Keep all personnel clear of the pulse generator area during operation. Always check that the area is clear of personnel before charging the pulse generator.

3.1.2. Pneumatic Energy Hazard

Although this equipment and its components are designed with adequate safety factors, the operator should be aware that a pneumatic energy (high pressure gas) hazard exists. The following safety precautions should be followed to minimise this hazard.

a. Always tie or chain a gas cylinder to a substantial structure to avoid the injuries and equipment damage that could result from its falling. A gas cylinder weighs 130 lb when empty. Its shape makes it unstable when set on its end unless properly secured;

b. Pneumatic energy of about 0.6 MJ is stored in a standard gas cylinder of 220 ft^3 at 2000 psig. Ensure that the heavy steel screw-on-nozzle cover is fitted to the gas cylinder before releasing the cylinder from its restraint;

c. Do not work on the equipment while the gas pressurized spark-gap switches are under operating pressure; and

d. Do not allow gas pressure in output switch to exceed 90 psig

3.1.3. Fire Hazard

Potential for an electrical fire exists in the control room and in the transformer oil of the HVPS tank. It is therefore recommended that the control room and pulser areas be equipped with Class BC fire extinguishers and that gas shutoff valves be positioned where you can reach them easily in case of fire.

3.1.4. Transformer Oil Hazard

The transformer oils recommended for use in the HVPS may pose a health hazard (in addition to the fire hazard described previously). Avoid prolonged or repeated contact with the skin, avoid getting oil in the eyes, and avoid accidentally ingesting it through eating or smoking. The manufacturer's Material Safety Data Sheet is included in Appendix A.

3.1.5. SF_6 Gas Hazard

WARNING
After exposure to electrical discharges, SF_6 can decompose into highly toxic gases. It should be scrubbed before being vented to open air.

Sulphur hexafluoride (SF_6) is 5.1 times heavier than air. The SF_6 from the output switch should be vented through a disposable water tank to remove most of the highly soluble by-products and to break down or partially dissolve the toxic by-products. The diffusion of the remaining by-products into the air will be slowed down, resulting in greater dilution. A copy of the Material Safety Data Sheet and the manufacturer's recommended safety precautions for SF_6 is included in Appendix A.

Although SF_6 is non-toxic, because it is so much heavier than air, a personnel suffocation hazard exists, and proper safety procedures must be followed. The pulse generator requires use of SF_6 at atmospheric pressure in the outer housing to provide electrical insulation of the Marx generator's, output switch, and peaking circuit. When you need to enter the pulse generator system for maintenance, the following safety precautions should be taken:

a. Ensure that all electrical circuits have been discharged;

b. Release gas pressure from the Marx switches and output switch;

c. Open SF_6 vent valve (if so equipped) and remove the pulser tank cover, or pump SF_6 from the tank;

d. Check that the SF_6 is completely removed using a reliable detector (such as a halogen detector); and

e. Use the buddy system when entering a tank. Always have someone outside the tank when personnel are inside.

WARNING

Never attempt to remove SF_6 by using the lower vent only without partially opening the top cover to allow air to displace the SF_6. Always work with more than one person present and ensure proper breathing safety equipment is on hand before entering the pulse generator.

3.1.6. EMP Hazard

The DREO EMP simulator produces intense electromagnetic fields in the vicinity of the transmission line structure. To avoid unnecessary exposure, all of the site crew should be inside one of the two shielded rooms with the doors closed when the pulse generator is fired.

3.1.7. Radiation Hazard

The thyratron located in the modified 40230 trigger generator produces soft X-rays. The X-rays are shielded in normal operation by the metal cover. Use caution when operating the trigger generator with the cover removed.

3.1.8. Capacitor Rupture

There is a remote possibility that a capacitor in the Marx bank will violently rupture during charging or discharging. The fibre glass tank should contain all debris but caution is required during clean-up since the capacitors are oil filled.

4.0 SPECIFIC PRECAUTIONS

4.1 Introduction

This section specifies precautions to be taken to deal with each of the hazards listed in Section 3 including special safety equipment required.

General safety procedures will include using the buddy system when working on high voltage circuits. Only trained operators will be allowed to operate the pulser system or enter the test area.

4.1.1 Marx Capacitors

The Marx capacitors store lethal voltages. No personnel are to enter the generator room during the charging and firing sequence.

Should high voltage remain on the Marx bank after a pulse, as indicated on the charging meters, the automatic dump systems will discharge it safely. The primary system has a redundant dump relay located in the power supply. Should both systems fail, use the following procedures.

a. First, keeping the area secure, attempt to trigger the Marx generator and discharge the generator into the load;

b. If that fails, manually bleed the Marx switch pressure from the control console and let the Marx generator self-fire into the load.

c. If the voltage is too low to cause self-firing, turn off the power supply and allow the energy to drain through the charge resistors and power supply, monitoring the voltage on the control console until both meters read zero. Enter the generator room and discharge the capacitors using the shorting bar.

4.1.2 Trigger Generator

The trigger generator capacitors are enclosed during normal operation inside the trigger generator cabinets. The capacitors should be shorted before maintenance is performed and before the polarity is changed. Refer to the operating instructions for the individual trigger generators.

To preclude a trigger pulse being generated while performing maintenance on the trigger boards or Marx switches, personnel entering the generator room should verify the high voltage is OFF on the trigger generator controller.

4.1.3 Compressed Gases

These potential energy hazards are unleashed only when the compressed gas is not contained. Safety precautions are therefore directed to insuring the mechanical integrity of the cylinders and regulating the gases to lower working pressures at the cylinder outlets. The gases will be regulated at the cylinder to no more than 90 psig. Gas cylinders will be transported and handled so as to avoid severe mechanical shock. Gas cylinders will be properly secured to a gas bottle rack when brought to the site. Steel nozzle covers will be attached over the necks of the cylinders whenever the cylinders are moved.

4.1.4 Gas Toxicity

A SF_6 infusion from a leak in the gas regulators, the gas lines or the pulser housing will mix into the air of the generator building. Check SF_6 leakage on a regular basis using the portable SF_6 sensor. If a leak exists, the building can be ventilated by opening all of the doors.

The pulser housing must be drained before being entered. Open the top cover, and open the drain flange at the bottom of the housing, routing the SF_6 outside. Ventilate the housing with a fan prior to entry.

Output switch purge gases will be scrubbed and vented outside the building.

4.1.5 Switch Failures

The trigger generator switches are enclosed in the trigger generator cabinets, which will shield any flying debris. The Marx and output switch housings are mechanically stronger, but the possibility of rupture still exists. When working inside the pulser tank, the Marx and output switch pressure will be reduced to 10 psig maximum. During the charging and firing sequence, personnel will remain behind barriers or in the screen room. The pulser housing represents a sufficient barrier.

4.1.6 Fire

Appropriate fire extinguishers shall be used on pulser fires to minimize equipment damage. The phone number of the fire department is posted near the telephone.

5.0 GENERAL RULES

5.1 From the moment the crew enters the site, one crew member, the site safety officer, assumes responsibility for the safety of personnel and equipment.

5.2 The safety officer is in possession of ALL site keys. This includes the key to the security gate, the keys to all doors within the site AND THE FIRING KEY. (There is a second set of keys held by someone outside the site who can let people in during an emergency.)

5.3 The gate is unlocked only during entry or exit of the site crew.

5.4 The firing button is connected to an interlock circuit. This circuit opens when any of the following happen:

a. the door to the generator room is opened;

b. the door to the measurement room is opened; and

c. the door to the control room is opened.

5.5 The interlock circuit is not self-closing. That is, current flow is not resumed immediately on closure of an interlock switch. The circuit must be manually closed via a reset switch after it has been opened. There are audible and visible signals when the circuit is opened. The audible signal is temporary; the visible signal remains on until circuit reset. These signals are given in the control room where the de-energizer button is located. The switches are failsafe switches, that is, they fail open.

5.6 The door to the terminator building is unlocked only while the building is occupied. This building is only occupied during the walk-around at the start of a working day.

5.7 During maintenance on the generator, grounding straps are to be connected to the charging leads and also to the high voltage parts that are being worked on. It is often helpful to flag these with large coloured flags to make sure they are removed before the pulser is operated. Firing the pulse with grounding straps in place can cause serious damage to the pulser.

5.8 Any time equipment is being operated there should be at least two people present and in communication with each other. These people are responsible for each other's safety, and have been instructed how to act during any type of accident. This is especially important during maintenance, when less than the normal crew is on hand. At any time, there must be at least one person not at risk.

5.9 All people must be properly trained for their jobs and responsibilities including familiarity with the safety procedures.

5.10 All personnel on site must be inside a closed shielded room during firing. (Normally, there are only two shielded rooms on site - the control room and the measurement room.)

5.11 The security fence is to be posted all around with high voltage warning signs.

5.12 All equipment in the EMP facility (except equipment in the test volume) must be connected to safety ground.

5.13 Maintenance and construction personnel are to be accompanied by a member of the EMP group.

5.14 The lightning cables are to be connected whenever the pulser is not being used.

5.15 SF_6 exhausts are to be on the side of the generator building that is opposite to the fresh air intake for the air handling unit.

5.16 The site is to be kept tidy at all times - there must be no unnecessary equipment lying about. All unused equipment, cables, tools must be in their assigned storage areas.

6.0 SYSTEM OPERATION

6.1 Start of Working day Check List

a. Count noses on entry to the site.

b. Area walk-around shows everything in order and nothing unusual.

(i) Check for damage to strain relief bars, motion take-ups, hangar ropes, anchor ropes and connections in both generator and terminator buildings.

(ii) Check for damage to the generator window and the terminator window.

(iii) Check for damage to the termination. Check resistors, motion take-ups, hangar ropes, and grounding straps.

(iv) Check for damage to the rigging. Check the ropes and connections to the pole anchors. Check the transverse and longitudinal suspenders.

(v) Check for unusual geometry and/or sag in both sets of transmission line wires.

(vi) Check for damage to any equipment under test.

c. Lightning cables removed from the output of the generator. Firing the generator with the lightning cables in place can cause serious damage to the generator.

d. Telephones in both rooms are in working order.

e. Test for SF_6 in both rooms of the generator building. Use a portable SF_6 detector for this.

f. Turn on the hazard light to indicate that testing is in progress.

g. De-energizing button tested and working.

h. Gates locked.

6.2 Daily System Start-up

Care must be takin in starting up the system to ensure no damage is done to the pulser. Follow these steps:

a. Begin system start-up with an inspection walk around the pulser;

b. Check air and SF_6 cylinders; they should be on line and the gasses regulated to 90 psi;

c. Check that diagnostic, control and gas lines are properly connected;

d. Inspect all viewports and covers. Make sure they are securely fastened;

e. Apply 110 V ac power to the auxiliary systems;

f. If operation requires it, check the SF_6 level in the pulser tank. The level should be to the top of the flat portion of the tank. If the gas level is below the top of the flat portion of the tank, refer to Section 5.7 of reference 8.1 for proper filling procedure;

WARNING
The pulser tank is not rated for positive pressure.

g. Turn the power on at the control console with the circuit breaker, located on the front panel of the patch panel;

h. Turn on the power supply controller panel by turning key switch to ON;

j. Verify the POWER indicator is illuminated on all control panels. Perform lamp test and replace any defective LEDs;

k. Turn on trigger generator filaments;

m. Set the trigger generator pressure to 50-52 psig, 50-100 cc/min. Make sure the GAS INTERLOCK READY indicator illuminates; and

n. When the FILAMENTS READY lamp illuminates, the system is ready to begin the shot cycle.

6.3 Normal Shot Cycle

The following instructions outline the procedure for the Normal Shot Cycle. (Tables 5.1 through 5.4 are enclosed as Appendix B).

a. Select the output voltage in the range of 200 kV - 600 kV.

b. Select the charge voltage from the Charge % vs Output Voltage curve. Figure 5.2

c. Pulse generator operator (hereafter referred to as "the operator") sets the desired charge voltage on the HVPS controller.

d. The operator selects desired triggering mode: AUTO for automatic trigger at charge complete, or NORMAL for manual or remote triggering.

e. The value of capacitance in the primary circuit HVPS needs to be adjusted to keep the charge current, and therefore, the pulse generator charge time in the correct range. Table 5-1 gives the charge rate selector setting ar charge voltage range. The charge rate selector is located on the HVPS.

f. The operator sets the appropriate Marx gas pressure. Refer to the Marx operating curves (Figure 5-3).

g. The operator sets the appropriate output switch spacing and gas pressure. Refer to the output switch operating curves (Figures 5-4).

h. Verify diagnostics are ready.

j. Prior to firing, the operator must ensure that all of the site crew is inside one of the shielded rooms;

k. The generator room is examined through the screened wall of the control room to ensure that everything is in order;

m. The operator checks through the window of the generator room and inspects the video monitor to ensure no unauthorized personnel are on site and that everything is in order;

n. Obtain clearance from the measurement room to fire the pulse generator.

p. The operator presses interlock RESET to clear interlocks. All interlocks except trigger generator must be closed.

q. The operator turns ON trigger generator high voltage.

r. The operator presses interlock RESET to attain 'interlocks complete' status.

s. The operator presses READY to arm pulse generator.

t. The operator warns of impending shot.

u. The operator re-checks all system gas pressures for proper values.

v. The operator presses START button when the dump relay is open.

w. The operator announces "Charging".

x. Allow the Marx generator to reach full charge and stop automatically or stop charge by pressing the "STOP" button on the HVPS controller.

y. After charge is complete, the operator fires pulse generator by pressing READY TO FIRE button, or pulser is fired automatically in AUTO mode.

z. The operator presses DUMP button and observes that the dump relay closes and power supply voltage and current meters indicate zero, and trigger generator HV is OFF.

aa. The operator should verify the Marx and output switch gas control systems have automatically started purging the switches.

bb. The operator fills in the pulser log book (see example in Appendix B) as required.

6.4 Low Voltage Operation [8.1]

The Marx generator has the capability of operating at pulser voltages below the standard 200 kV lower limit. To use this lower voltage capability, the Marx switches must be replaced with a second set of switches having a small or electrode spacing. These switches are identical to the standard switches, except the housings are scribed with the letters 'LV'.

CAUTION
Be very careful not to intermix the types of switches in the Marx

The following steps should be performed when configuring the Marx generator for low voltage operation.

a. Drain SF_6 from the Marx generator tank;

b. Lower the gas pressure in the Marx switches to zero psig;

c. Short the Marx generator at each stage using a shorting bar;

d. Disconnect the trigger resistor leads at the irradiation pin of every switch;

e. Disconnect both gas lines from every switch;

f. Remove the bolts holding the switch to the bus work, and extract the switch, retaining the bolts and washers. Note orientation of the switch trigger pins;

g. Install the alternate switches by positioning the switches with the trigger pins oriented toward the trigger leads, and reversing steps f to d;

h. Purge the switches for one minute;

j. Perform a charge/dump test to verify proper connects as outlined in 4.6 of reference 8.1; and

k. The Marx tank can now be filled with SF_6, if necessary. This is not required at pulser voltages below 200 kV.

6.5 System Shutdown

To shut down the pulse generator at the end of the operating day perform the following steps, starting at the control console:

a. Press the DUMP pushbutton on the power suppy controller.

b. Verify charging meters indicate zero voltage. If not, see Section 4.2.2 of reference 8.1.

c. On the power supply control panel, turn the key switch to OFF.

d. Turn OFF trigger generator high voltage and filaments at the trigger generator controller.

e. Reduce all gas pressures to 30-40 psig, no flow through the trigger generator.

f. Turn off AC power to the control console.

g. Turn off AC power to the auxiliary control enclosure.

> WARNING
>
> Use a high voltage discharge shorting bar to ensure the voltage is discharged if entering pulse generator. If entering, allow all insulating gas to drain from the pulser tank and ventilate thoroughly.

6.6 Emergency Procedure

If an emergency arises, pressing the DUMP pushbutton on the HVPS control panel will abort the charge and discharge the high voltage. This action can be taken at any time prior to firing. Check that the dump relay DUMPED indicator lights and the voltage and current meters read zero. Check that the trigger generator high voltage has been automatically turned OFF.

6.7 Manual Abort

> WARNING
>
> Pressing the STOP button will stop the charge cycle but will leave high voltage in the system. Press the DUMP button to discharge system and turn off trigger generator HV.

The charge cycle can be stopped at any point in the cycle by pressing the STOP button or the DUMP button on the HVPS control panel. The STOP button stops the charge but does not remove the high voltage from the system. Subsequently pressing the START button will reinitiate the charge cycle. Pressing DUMP button will stop the charge and remove the high voltage. If no other shutdown actions have been taken following a DUMP button action, the charge cycle can be restarted by resuming the operating procedure described in Section 5.4.2.

6.8 Manual Discharge

Should the high voltage remain on the Marx bank after firing, as indicated on the charging meters, discharge the Marx capacitors following the procedure described in Section 4.1.

6.9 End of Working Day Check List

a. Turn off the generator;

b. Check Marx charging meters marx;

c. Pulser and transmission line grounded with shorting stick and then lightning cables attached.

d. All gases flow meter and turn off at the bottles.

e. Generator building locked.

f. Daily operation log completed.

g. Measurement equipment room turned off and measurement building locked.

h. Keys replaced.

7.0 MAINTENANCE AND TROUBLESHOOTING

Section 6 of reference 8.1 contains instructions and preventive maintenance checks and services to be performed at scheduled intervals, and corrective maintenance actions to restore the system to the specified operating conditions after failure has occurred.

Devices for the protection of both operator and components have been included in the equipment design. However, for safe maintenance operation, the user should follow certain safety precautions. Such as:

a. Disconnect equipment from the main power source.

b. Use an insulated, hand-held shorting bar to discharge and ground all capacitors before touching high-voltage circuits. Lethal voltages may be present in the equipment even after firing.

WARNING

High voltage is used in the operation of this equipment. Death on contact may result if safety precautions are not observed. Check that each capacitor is discharged, shorted and grounded before you work on the Marx generator and the HVPS.

WARNING

The high voltage used in the trigger generator may be lethal. Before working in high-voltage areas, turn off and ground all high-voltage capacitors.

WARNING

If the charge lead is removed from an ungrounded capacitor, relaxation may occur and the capacitor may recharge to a dangerous level after several hours.

8.0 REFERENCES

8.1 Operation and Maintenance Manual for the DREO 600 kV EMP Pulse Generator; Maxwell, Report MLR-3977, February 1992.

8.2 A Study of the Environmental Impact of the EMP Simulator; M.G. Pelletier, G.Y Delisle; Universite Laval, Report LRTS-90-8803, January 1990.

MATERIAL SAFETY DATA SHEET

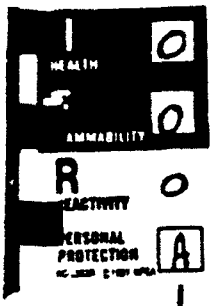
APPENDIX A

Sulfur Hexafluoride

LIQUID CARBONIC
SPECIALTY GAS CORPORATION

Revision April 1986

24 Hour Emergency Phone Numbers: (504)673-8831; CHEMTREC (800)424-9300



SECTION I--PRODUCT IDENTIFICATION

CHEMICAL NAME: [redacted]Hexafluoride
COMMON NAME AND SYNONYMS: Sulfur Hexafluoride, Sulfur Fluoride
CHEMICAL FAMILY: Inorganic Fluoride FORMULA: SF_6

SECTION II--HAZARDOUS INGREDIENTS

MATERIAL	VOLUME %	CAS NO.	1985-6 ACGIH TLV	UNITS
Sulfur Hexafluoride	99.9%	2551-62-4	8 Hr. TWA	1000 PPM
			STEL	1250 PPM

SECTION III--PHYSICAL DATA

BOILING POINT (°F.) Sublimes -82.8°
SPECIFIC GRAVITY (H_2O=1) @1 ATM. and @ 70°F - 6.4
VAPOR PRESSURE @ 70°F 319 PSIA % VOLATILE BY VOLUME 100%
VAPOR DENSITY (AIR=1) @70°F 5.13 EVAPORATION RATE (BUTYL ACETATE=1) Rapid
SOLUBILITY IN WATER Slightly
APPEARANCE AND ODOR Colorless, odorless gas

SECTION IV--FIRE AND EXPLOSION HAZARD DATA

FLASH POINT (METHOD USED) Non-flammable FLAMMABLE LIMITS LEL N/A UEL N/A
EXTINGUISHING MEDIA: Use media appropriate for surrounding fire

SPECIAL FIRE FIGHTING PROCEDURES: Use water spray to cool fire exposed containers. Use self-contained breathing apparatus as SF_6 can decompose at high temperatures to give off toxic and corrosive fumes.

UNUSUAL FIRE AND EXPLOSION HAZARDS: Vapors are five times heavier than air and will tend to accumulate in low places. SF_6 can be an asphyxiant in enclosed areas.

SECTION V--HEALTH HAZARD DATA

THRESHOLD LIMIT VALUE: TWA is 1000 PPM
EFFECTS OF OVEREXPOSURE: Sulfur hexafluoride is non-toxic. However it can act as an asphyxiant in high concentrations. Symptoms are headache, dizziness, labored breathing and eventual unconciousness.

EMERGENCY AND FIRST AID PROCEDURES: If inhaled move to fresh air and obtain prompt medical attention. Administer oxygen. Give artificial respiration if not breathing. Rescue personnel should be equipped with self-contained breathing appartus. In case of contact with Liquid SF_6, flush affected areas with lots of warm water to reduce tissue freezing.

Sulfur Hexafluoride is not listed as a carcinogen or potential carcinogen by NTP, IARC Monographs, and OSHA.

SECTION VI--REACTIVITY DATA

STABILITY: UNSTABLE ( ) STABLE (X)

CONDITIONS TO AVOID: N/A

INCOMPATABILITY (MATERIALS TO AVOID): None

HAZARDOUS DECOMPOSITION PRODUCTS: Lower fluorides of sulfur

HAZARDOUS POLYMERIZATION: MAY OCCUR ( ) WON'T OCCUR (X)

CONDITIONS TO AVOID: N/A

SECTION VII--SPILL OR LEAK PROCEDURES

STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED: Evacuate personnel from affected area. Avoid high concentrations in confined space. Provide ventilation. Do not re-enter area without appropriate protective equipment.

WASTE DISPOSAL METHOD: Vent to atmosphere. Follow any applicable local, State, or Federal regulations.

SECTION VIII--SPECIAL PROTECTION INFORMATION

RESPIRATORY PROTECTION: If required - self contained breathing apparatus.

VENTILATION: LOCAL EXHAUST ( )
MECHANICAL (GENERAL) (X) Provide adequate ventilation in low areas to be below allowable TLV.

PROTECTIVE GLOVES: Leather EYE PROTECTION: Goggles or safety glasses

OTHER PROTECTIVE EQUIPMENT: Safety shoes recommended for cylinder handling

SECTION IX--SPECIAL PRECAUTIONS

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORING: Protect cylinders from physical damage. Store in cool, dry, well ventilated area. Cylinders should not be exposed to temperatures over 130°F. Follow normal compressed gas storage practices. Cylinders should be stored upright and firmly secured to prevent falling over. SF_6 exposed to electric arcs may contain toxic by-products. Keep valve caps and plugs tight and in place.

OTHER PRECAUTIONS: Use only DOT or ASME coded storage containers. Use a check valve or trap in the SF_6 discharge line to prevent hazardous backflow. Cylinders must not be recharged except by or with consent of Liquid Carbonic. Refer to CGA bulletin SB-2 oxygen Deficient Atmospheres" and pamphlet P-1 "Safe Handling of Compressed Gases in Containers."

SHELL OIL COMPANY
SHELL CHEMICAL COMPANY
SHELL DEVELOPMENT COMPANY
SHELL PIPE LINE CORPORATION

MSDS 6003-1

HAZARD RATING

1 / 1 0

MATERIAL SAFETY DATA SHEET

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SECTION I

Shell Oil Company	713-473-9461
One Shell Plaza, P. O. Box 2463, Houston, TX 77001	
	Shell DIALA(R) AX Oil
Hydrocarbons	Code 63702

SECTION II HAZARDOUS INGREDIENTS*

COMPOSITION	%	SPECIES	LD_{50}		LC_{50}	
			gas	dermal	concentration	exp.
Petroleum hydrocarbons	>99.5	Rat/Rabbit	.5 g/kg	2 ml/kg		
Phenolic Oxidation Inhibitor	<0.5					

The petroleum hydrocarbons in this product contain a mixture of paraffinic, naphthenic, aromatic, and small amounts of heterocyclic hydrocarbons. As with other petroleum oils, the aromatics contain polycyclic compounds of various concentrations and structures. Some of these polycyclics may be those which have been shown to induce cancer in animals under laboratory conditions. Epidemiologic studies have suggested the possibility of skin cancer induction in man after prolonged and repeated contact with oils containing these materials under conditions of poor personal hygiene. Inhalation of mists arising from oils containing these materials may also present a cancer hazard.

SECTION III PHYSICAL DATA

Boiling point, °F		Specific gravity (H2O = 1) @ 60°F	0.87
Vapor pressure (mm Hg)		Percent volatile by volume (%)	NA
Vapor density (air = 1)	NA	Evaporation rate (butyl acetate = 1)	NA
Solubility in water	Nil		
Appearance and odor	Light colored oil		

SECTION IV FIRE AND EXPLOSION HAZARD DATA

Flash point (Method used)	300°F PMCC	Flammable limits	LEL / UEL
Extinguishing media	Use CO_2, dry chemical, alcohol foam.	NA	
Special fire fighting procedures	Do not use water except as a fog.		
Unusual fire and explosion hazards	None unusual. CO, CO_2 and oxygenates can be formed during combustion.		

*Established by Shell Oil Company

MSDS 6003-1

MSDS 6003-1 SECTION V HEALTH HAZARD DATA

Vapor - not established. Oil mist - 5 mg/m³

Pulmonary irritation possible. Defatting action on skin. Prolonged or repeated contact may cause skin disorders such as dermatitis, folliculitis, oil acne or even skin cancer.

Eye - flush with water for at least 15 minutes. Skin - remove oil by wiping or applying waterless hand cleanser, followed by washing with soap and water. Remove all contaminated clothing. Ingestion - induce vomiting if conscious and consult medical personnel.

SECTION VI REACTIVITY DATA

		X	Mist formation, excessive heat.

		X	

SECTION VII SPILL OR LEAK PROCEDURES

Absorb with clay, diatomaceous earth, or other inert material.

WASTE DISPOSAL METHOD
Controlled burning in compliance with local regulations or bury in approved landfill.

SECTION VIII SPECIAL PROTECTION INFORMATION

NIOSH-approved respirator to avoid exposure to hot vapor or mist.

As required to prevent exposure to vapor or mist.

Oil resistant (rubber)	
OTHER PROTECTIVE EQUIPMENT Appropriate clothing to avoid skin contact.	Goggles if oil is being sprayed or splashed.

SECTION IX SPECIAL PRECAUTIONS

Avoid breathing oil mist and vapors. Avoid skin and eye contact. Airborne mist should be kept substantially below the nuisance TLV for oil mist.

OTHER PRECAUTIONS Launder contaminated clothing before using. Discard leather goods when contaminated. Wash before eating or smoking.

Product Safety & Compliance
Oil & Chemical Products
Shell Oil Company
January, 1979

DREO 600 kV Pulser — Shot Log — Test Series:______________

Date	Shot Number	Charge Voltage %	Marx Switch Pressure psig	Marx Switch Gas	Output Switch Pressure psig	Output Switch Gas	Output Switch Spacing turns	Reference Field mT	Notes

Figure 5-1. Test shot log

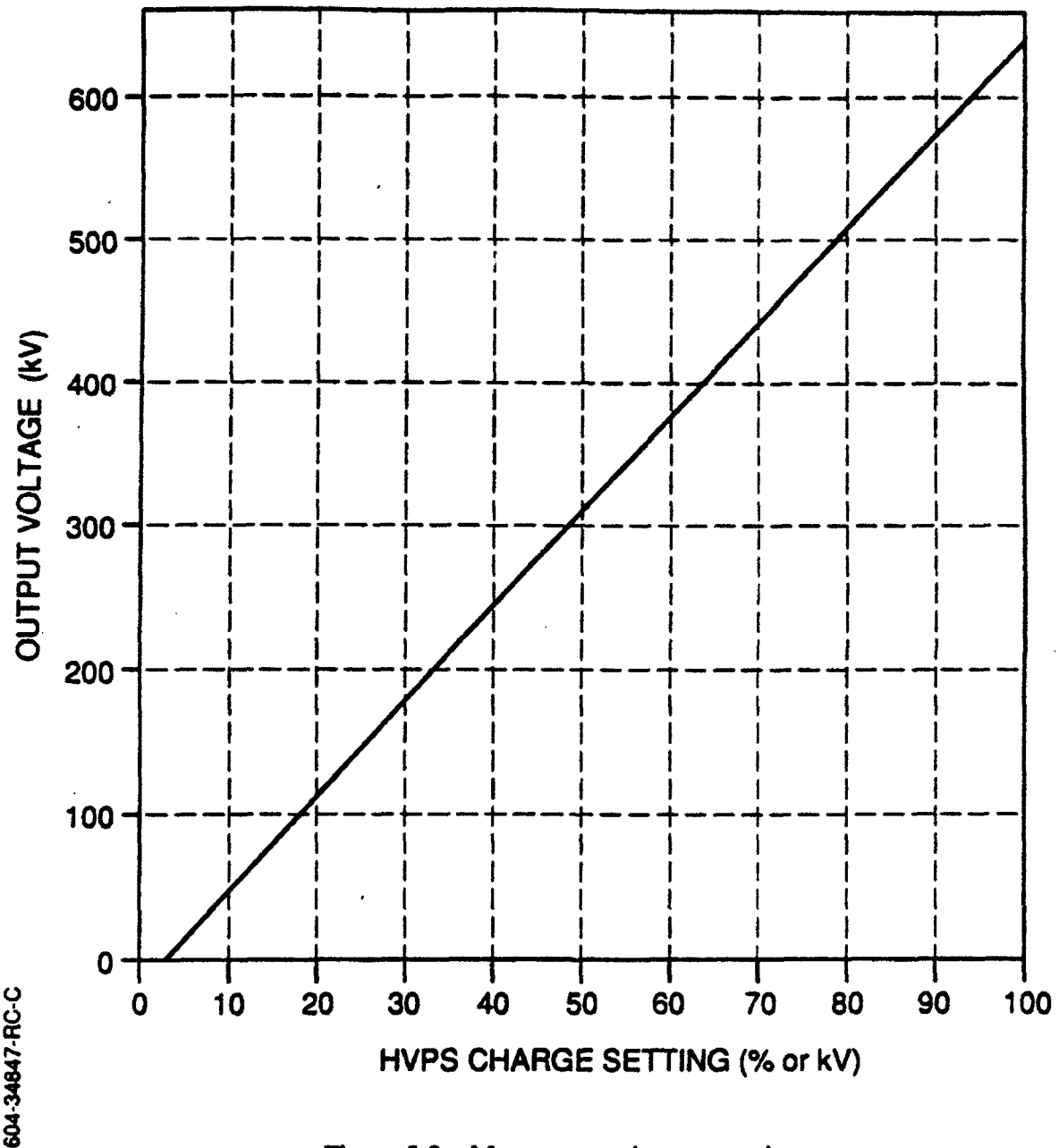

Figure 5-2. Marx stage voltage operating curve

TABLE 5-1
HVPS CHARGE RATE SELECTOR SETTINGS FOR PULSER CHARGE VOLTAGE

S1	S2	CHARGE VOLTAGE RANGE
IN	IN	70 - 100 %
IN	OUT	22 - 70 %
OUT	OUT	0 - 22 %

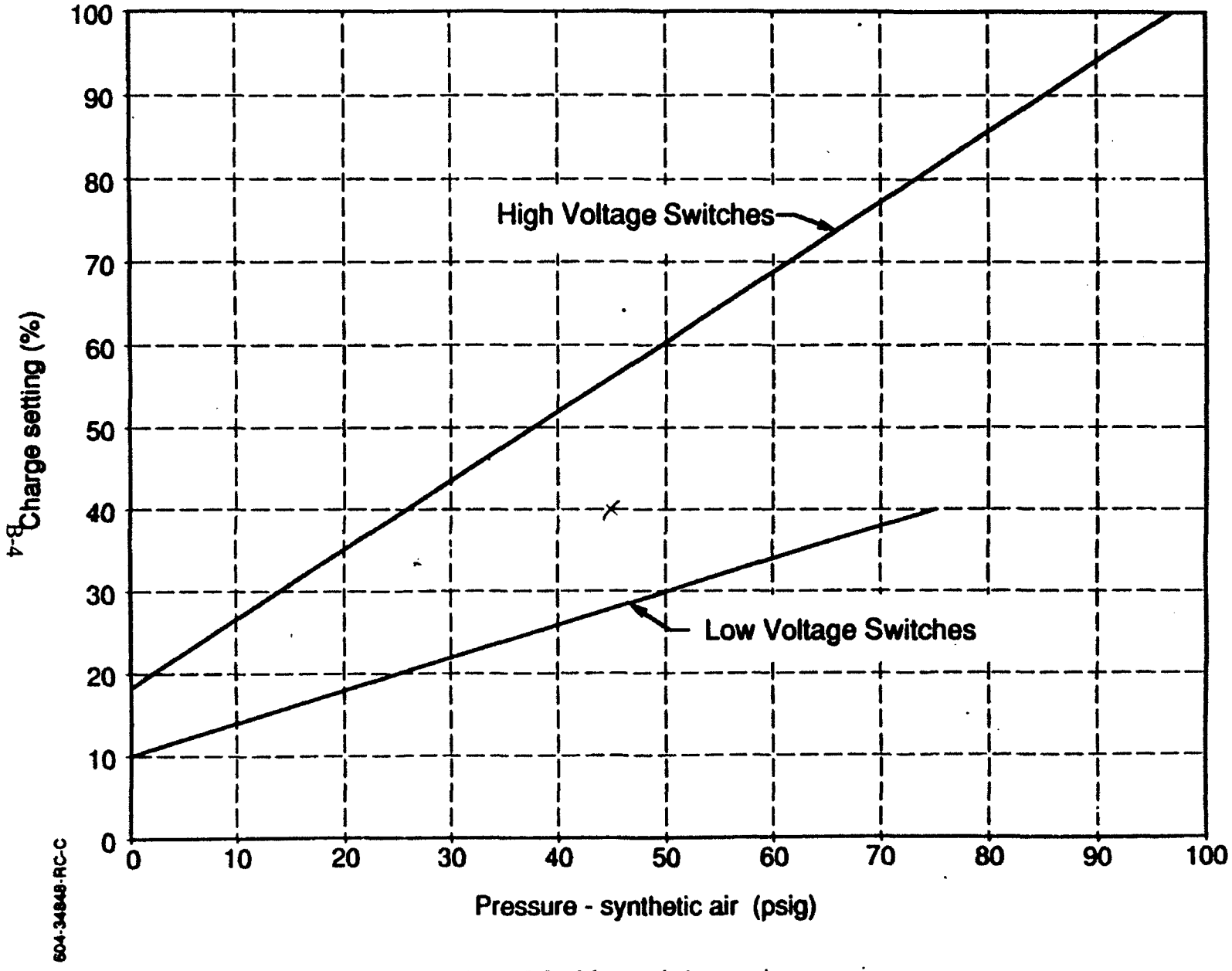

Figure 5-3. Marx switch operating curves

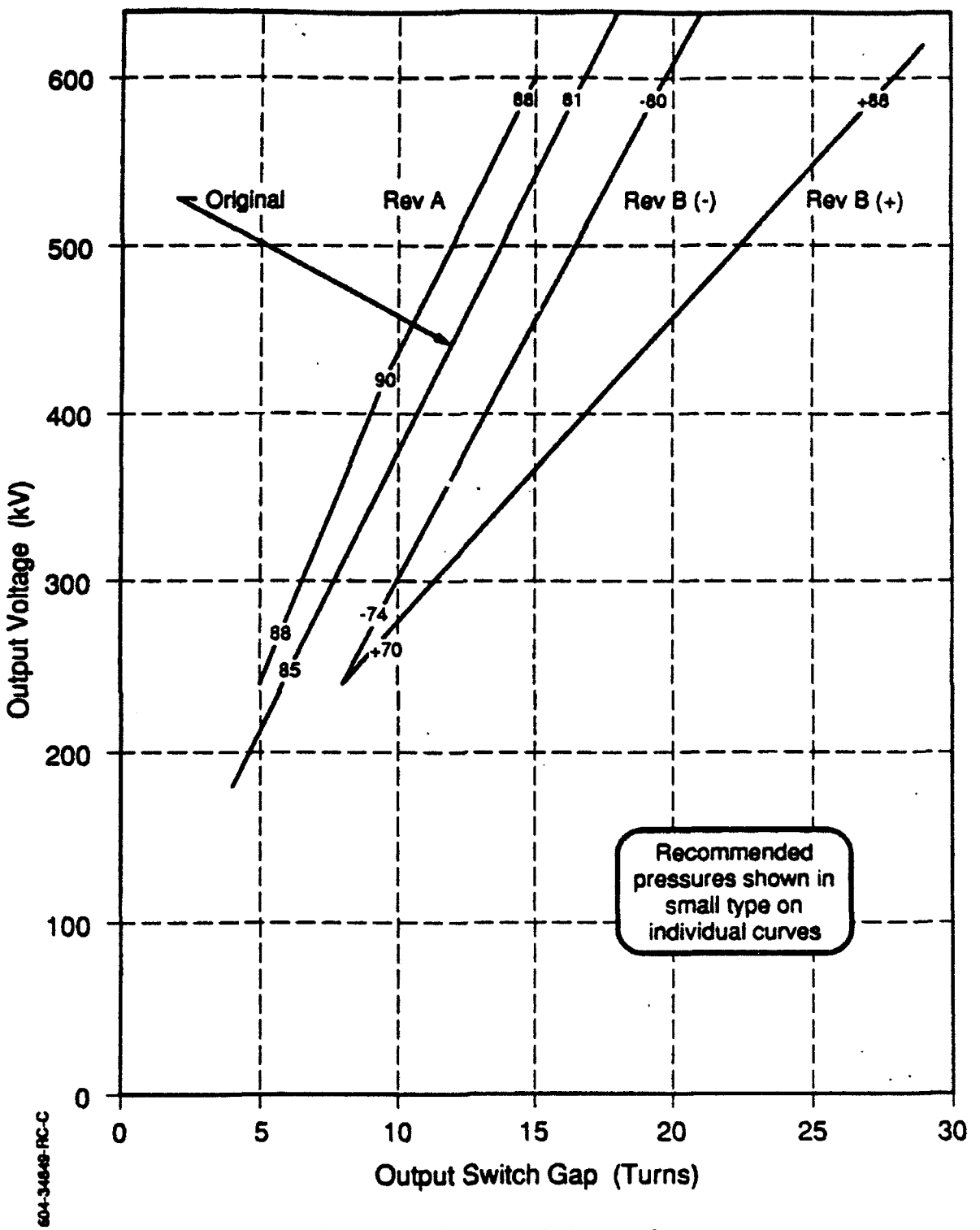

Figure 5-4. Output switch operating curves

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